Fisheries and Oceans Canada | Pêches et Océans Canada

Canadian Stock Assessment Secretariat
Research Document 99/148

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Secrétariat canadien pour l'évaluation des stocks
Document de research 99/148

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Assessment of the Scotian Shelf silver hake population in 1998

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ISSN 1480-4883
Ottawa, 1999

Canada

Abstract

The status of the Scotian Shelf silver hake population in 4VWX was evaluated using updated catch-at-age (1979-98), research surveys, commercial CPUE, and biological indices. An analytical assessment of yield was not possible, as the model results could not be accepted due to a large retrospective pattern in the estimates of population numbers. Other attributes of stock status were not consistent. Recruitment will likely be above average in 2000, and resource concentration and geographical range distribution exhibit positive trends. However, survey biomass is very low and total mortality estimates from the survey are high. The extreme values of these important indicators are cause for concern. Other attributes, such as length-at-age, condition, and size at maturity, while not at near lowest levels, are below long term averages. Under these circumstances, catches should be restricted to that seen from 1997-99.

Résumé

L'état de la population de merlu argenté du plateau néo-écossais dans les divisions 4VWX a été évalué au moyen des données sur les prises selon l'âge (1979-1998) mises à jour, des relevés de recherche, des CPUE de la pêche commerciale et des indices biologiques. Il était impossible d'effectuer une évaluation analytique du rendement, car les résultats de modélisation n'ont pu être acceptés en raison du fort caractère rétrospectif de l'effectif estimé de la population. D'autres caractéristiques concernant l'état du stock n'étaient pas cohérentes. Le recrutement sera probablement supérieur à la moyenne en 2000, et la concentration et la répartition géographique de la ressource présentent des tendances positives. Cependant, les relevés indiquent une biomasse très faible et une mortalité totale estimée très élevée. Les valeurs extrêmes de ces indicateurs importants sont préoccupantes. Les autres caractéristiques, comme la longueur selon l'âge, la condition et la taille à maturité, même si elles n'approchent pas les niveaux les plus bas, demeurent inférieures aux moyennes à long terme. Dans ces conditions, il faudrait limiter les prises aux valeurs obtenues entre 1997 et 1999.

The Fishery

The silver hake fishery has been conducted on the Scotian Shelf since the mid-1960's, primarily by the distant water fleets of Russia, Cuba and Japan in the early years. Prior to 1977, fishing on the Scotian Shelf was unrestricted in terms of area, mesh size and season. During this period fishing was conducted over the entire shelf, and the use of trawl mesh as small as 40 mm was common. Following the extension of jurisdiction to 200 miles by coastal states in 1977, Canada implemented the Coastal Fisheries Protection Act, which restricted fishing for this species to the seaward side of the Small Mesh Gear Line (SMGL, Fig 1), west of 60° W longitude, with a minimum mesh size of 60 mm. On an experimental basis, a portion (4-6 vessels) of the fleet was allowed to fish landward of the SMGL during 1978 and 1979. From 1980 through 1983, fishing was permitted by condition of license in an eastern extension of the Silver Hake Box as far as 57° W longitude; from 1984 to present this eastern extension has been restricted to 59° W longitude. In 1994 further restrictions were introduced to minimize incidental catches of cod, haddock and pollock in the silver hake fishery. These included a repositioning of the SMGL to prevent fishing in depths less than 190 m (Branton, 1998) and the use of a separator grate in the lengthening piece of the trawl.

Canadian fishing interests have engaged in experimental harvesting of this species since 1975, although until 1995 these efforts were developmental in nature (Showell and Cooper, MS1997). From 1995 to present a commercial fishery has been conducted by the Canadian tonnage class 3 (< 65') mobile gear fleet in and around Emerald and LaHave basins (Fig. 1). Based on concern over the harvesting of small fish in these areas, 55 mm square mesh was used by some vessels in 1998, rather than the traditional 60 mm diamond, and it's use was made mandatory in 1999. While experimental evidence had suggested this change to 55 mm square mesh would be effective in releasing small silver hake (Cooper, 1995), it's implementation in the commercial fishery differed from the experimental protocol. The tensile strength of the twine used to manufacture the square mesh was lower than that of traditional diamond mesh, and potential solutions such as increasing the twine diameter or knitting double twine were not considered practical. As a result, 90 mm topside chafers were required to support the codend during haulback, potentially blocking the meshes and mitigating the benefits of the square mesh. In recognition of this problem, guidelines for the use of topside chafers were developed in 1999 in consultation with industry. If a topside chafer was necessary, a 110 mm square mesh was thought provide the highest level of escapement, and the use of this gear configuration was implemented as of May 1, 1999 while other potential solutions were examined.

Nominal catches from this stock range from 300,000 tons in 1973 to 8,000 tons in 1994 (Table 1). Catches by the foreign fleet were generally high during the mid to late 1980's, with catches in recent years much lower (Table 1, Fig. 2). As the inshore Canadian fishery has developed, the proportion of the catch harvested by each fleet component has changed, and in 1998 the catch by the inshore fleet exceeded that of the offshore. This trend has continued in 1999, with the preliminary catch from Emerald and LaHave Basins in excess of 5,000 mt, while the catch by Cuban vessels fishing offshore under Canadian allocations has dropped to less than 4,000 mt (Fig. 3).

Distribution of fishing effort through the year has also changed. While generally the offshore fishery has been conducted from April to August, in 1998 a single Cuban vessel remained in the Canadian zone until December, although the catch for this period was very small (100 t). The inshore fishery also persisted late in 1998, with almost 20% of the catch coming from the last quarter of the year (Fig. 4).

Recent scientific advice, TAC's and catches ('000 tons) are as follows:

Year	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999
Advice	167	235		100	105	75	51	79	64	50	65	**
TAC	120	135	135	100	105	86	30	50	60	50	55	30
Catch	74	91	69	68	32	29	8	18	26	16	16	9[1]

[1] preliminary

** RAP Assessment

Removals at Age & Size and Weights at Age

While no foreign allocations of silver hake were caught in 1998, the fishery was conducted by two distinct fleets - Canadian flag vessels < 65' fishing in or near to Emerald and LaHave Basins, and the Cuban flagged tonnage class 7 vessels fishing seaward of the SMGL line under charter arrangements with Canadian partners. While modifications were made to the SMGL in 1994, several changes were subsequently made, and numerous exemptions granted to the Cuban fleet fishing in this area. Details of these changes are can be found in Branton, 1998.

Sampling for length composition and aging material from the Cuban vessels in 1998 was conducted by Canadian observers, with 100% of the fishery covered. Sampling levels were relatively high, with more than 400 length samples and 500 otolith pairs collected. The commercial removals at age were calculated using the same procedures as the previous assessment, using the Canadian observer unculled length frequency data and monthly age/length keys, by sex, constructed from Canadian aging data. Regressions of lengths and weights from the Canadian July research vessel survey were used to calculate

yearly alphas and betas by sex (Table 2) used in the calculation of sample weights and commercial mean weight-at-age. Age/length sampling for the August-December period was poor, therefore the catch-at-age for this period was constructed using the July age/length key and included with the July totals. Results are presented in Table 3.

Landings by the Canadian fleet were sampled routinely by DFO shore samplers in 1998, with 27 samples collected in total. Commercial removals at age and mean weight at age for this fishery were calculated on a quarterly basis, using the same methodology as used for the foreign fishery (Table 4).

As was the case in 1997 the majority of the Canadian catch was composed of age 2 fish, as compared to age 3 in the Cuban fishery (Fig. 5). Further, the extension of the Canadian fishery into the last quarter of the year resulted in the catch of substantial numbers of age 1 fish by this fleet.

The removals at age for 1977-96 were taken from the previous assessment (Showell, 1997a) to provide estimates for the period 1977-97 inclusive (Table 5).

Commercial mean weight-at-age was calculated for the same periods as the catch-at-age for each fleet, weighted by monthly catches. An aggregate mean weight-at-age was than calculated, weighting by the catches of each fleet. As has been noted in the past for this stock, commercial mean weight-at-age declined from 1992 to 1994, and has stayed relatively stable at this level in subsequent years (Fig. 6).

Size composition – Inshore fishery, 1998 & 1999

As has been noted in the past, the inshore Canadian fishery catches smaller silver hake than the fleet fishing offshore. These trends continued in 1998 and at least the first half of 1999 (Fig. 7 & 8), with the peak in the foreign catch consistently 2-4 cm larger than that of the Canadian catch. However, examining the Canadian size distribution on a quarterly basis (Fig. 9), some change in size distribution of the catch can be seen, with the proportion of fish < 21 cm reduced in 1998 and 1999. These changes coincide with the introduction of square mesh, and likely reflect changes in selectivity for this new gear. With the adoption in May 1999 of further changes in the attachment of topside chafers to prevent mesh blockage, selectivity would be expected to change again towards larger fish. A comparison of size distribution in the month immediately before and immediately after this change confirms this (Fig. 10).

Commercial Catch Rates

Multiplicative analysis of catch rates in the offshore component of the silver hake fishery using observer data showed no significant effect by country, month or NAFO area on catch rate (Smith & Showell, MS1996), indicating that a model with year alone has as much explanatory power as one which includes all four factors. Based on this analysis, a non-standardized catch rate series was developed using Canadian observer data (Fig. 11). The catch rates for this fleet have dropped from high levels in the period 1984-89, to relatively low levels since 1992. In 1998 fishery the catch rate rose slightly, but fell in 1999 to less than 1 ton/hour, which is the lowest in the time series.

An analysis of the effect of separator grates on silver hake catch rates by Halliday and Cooper (MS1997) indicates that the use of this equipment reduces the catch rate by about 5%. CPUE and effort, adjusted for this factor, are presented in Table 6.

The inshore fleet has been conducting a true commercial (as opposed to exploratory) fishery for silver hake, in and around Emerald and LaHave Basins only since 1995, rather than exploratory. Catch and effort statistics from the commercial landings (C/L) database for TC 1-3 vessels directing for silver hake are available. Catch per day and catch per hour show similar trends, with levels increasing in 1996, stable for 1997, then declining subsequently (Fig. 12). Changes to the manner in which this fishery is conducted may be responsible for this decline, as the inshore fishing areas were expanded to allow exploratory fishing and the development of new markets resulted in a year round fishery. Further, there are anecdotal reports from Industry of nets being fouled by an invertebrate species (likely a tunicate) which was present in high concentrations in the fishing areas.

In recent years the fishing effort directed towards the offshore component of the fishery has dropped dramatically, from a peak of approximately 3000 fishing days in 1991 to less than 500 in 1998 and 1999 (Fig. 13). Industry has noted a decline in fishing capability on the part of the Cuban fleet, citing poor mechanical condition of the vessels as reasons for reduced catch rates. However, equipment failure and other associated breakdowns, while reducing catches, may not necessarily reduce catch rates. An examination of fishing effort expressed as hours on 'bottom' per day (Fig. 14) does not show a significant decline in recent years, indicating that fishing practices may not be unusual when a vessel is operational. However, silver hake is a mobile species, and the loss of search capability associated with reductions in the number of vessels participating may adversely affect catch rates. As well, areas where catch rates have historically been high are on occasion not accessible because of the potential for gear conflict with the swordfish and offshore crab fleets. For these reasons catch rates for this fleet in recent years may not reflect abundance.

Industry Comments

Industry input on the status of the silver hake resource and fishery was solicited through the Silver Hake Advisory Committee. Membership in this group includes fishermen and plant operators involved in the silver hake fishery.

A number of issues were raised related to catch rates in 1999. Through most of the summer in the inshore silver hake fishery, large quantities of an unidentified algae or marine plant made fishing difficult, as the net quickly became fouled. Clearing the nets was almost impossible at sea – some vessels even used steam cleaners and high pressure washers with limited success. The defined fishing areas in the basins were also identified as a problem in harvesting this species, as it was felt in many cases the best fishing occurred near the boundaries of the polygons, and concentrations just outside the line could not be fished.

As was the case in 1998, the comparability of the foreign fishery in 1999 to historical efforts was questioned, with search capability and reliability of the vessels and fishing equipment identified as potential problems in the fishing success of the Cuban fleet.

Questions were raised over the effect of square mesh in reducing mortality on silver hake, with reports of large numbers of fish seen dead in the water during haulback.

The fishing areas currently defined for Emerald and LaHave Basins are relatively small compared to the number of vessels available. Fishing outside Emerald and LaHave Basins was therefore conducted under controlled conditions, with trips made to areas which appeared promising based on research vessel catch rates. The results of this exploratory fishing were not consistent. In some cases (Georges Basin) initial high catch rates did not persist, while fishing in test areas to the east of Emerald Basin resulted in generally poor catches.

Canadian Bottom Trawl Surveys

The July stratified random design groundfish survey has been conducted on the Scotian Shelf from 1970 using three Canadian research vessels (A.T. Cameron, Lady Hammond, and the Alfred Needler). A conversion factor of 2.3 is applied to the series prior to 1982 to account for the effect of vessel and gear changes between the A.T. Cameron and the other two vessels (Fanning, MS1985). No conversion factor is required between the Lady Hammond and the Alfred Needler.

Silver hake found in the Bay of Fundy area likely represent a portion of the Gulf of Maine/N. Georges Bank silver hake stock, rather than the Scotian Shelf stock. As was the case in the previous assessment of this resource, survey trends in both total numbers and biomass were therefore calculated for the Scotian Shelf portion of 4VWX only, excluding strata 484 through 495.

Survey trends in both numbers and biomass show relatively high abundance in the early to mid-80's, followed by a decline to relatively low levels over the period 1988-94 (Fig. 15). Abundance and biomass increased in 1995 and 1996, but has subsequently declined to low levels – similar to that seen in 1991-92.

Numbers at age for the Scotian Shelf strata only are presented in Table 7. As estimated by the 1998 survey, the two year old age group is about average in abundance – all other year classes, particularly the age 1 group, are below average in abundance.

Juvenile Survey

A standardized IYGPT O-group survey for this species was conducted since 1981 (1992 excluded) during the October-November period. Results of these surveys for the core strata (460-478) are presented in Table 8. This survey was discontinued in 1998.

Biological Indices

Previous analysis (Showell, 1997b) has shown both condition (weight for given length, Fig. 16) and mean length at age (Fig. 17) to have declined from 1971 to 1995, with the two factors combining to produce mean weights at age for ages 3 and 4 which were the lowest in the time series in 1994. With the addition of 1996 and 1997 survey data, a modest increase was seen over the previous low levels (Fig. 18). This rising trend appears to have stopped in 1998, and the mean weight at age continues to be low for these age groups.

Maturity observations have been routinely collected for this species on the July RV survey. The survey immediately proceeds the spawning period for silver hake, and this timing allows accurate distinction between mature and immature fish. Length of 50% maturity has declined over the time series (Fig. 19), with females declining from about 27 cm in the 1971 to 1981 period, to approximately 23 cm from 1991 to present. Males show similar trends, with length of 50% maturity generally greater than 23 cm from 1971 to 1980, compared to 19 or 20 cm in recent years. Changes of this nature have been attributed to a population undergoing stress (Trippel, 1995). Given the early maturation of silver hake, significant declines in length of maturity for this species may approach a physiological limit for spawning.

Environmental Considerations

Environmental conditions play an important role in recruitment success for many gadoid species. For example, Frank *et al*, 1994 found correlations between environmental signals and yearclass strength for 4VsW cod which could be used to predict recruitment. Silver hake is a species with a higher temperature preference than most gadoids on the Scotian Shelf, and might be expected to be adversely affected by cold water events. In 1997 and early 1998, a persistent mass of cold water moved onto the Scotian Shelf, lowering the bottom temperatures of Emerald and La Have basins by several degrees C (Drinkwater *et al.*, 1998). This event coincided with the disappearance of the 1997 yearclass, which had been thought to be abundant as O-group (Table 8), but appeared below average at age 1 in the subsequent July RV survey (Table 7).

Near bottom temperature anomalies in Emerald Basin were compared with RV silver hake abundance at age 1 from 1971 to 1999. While low recruitment coincided with negative temperature anomalies in several cases, overall the relationship was poor (Fig. 20). Similar comparisons in adjacent areas produced similar results.

Estimation of Parameters

Sequential Population Analysis

The adaptive framework (ADAPT, Gavaris, 1998) was used to calibrate an age based sequential population analysis. An ACON compiled version of ADAPT was used to minimize the non-linear least squares gradient technique (the Malquardt algorithm). The Canadian July R/V survey for strata 440-483 (excludes Bay of Fundy) was used as a tuning index from 1983 onward only, as the survey vessel changed in that year, and calibration coefficients for silver hake were not considered reliable. Tracking of cohort strength in the is difficult for older ages, and as a result the ages 1-6 were used to calibrate the analysis. Commercial CPUE from the foreign fishery had been used as tuning index in the previous assessment, but was excluded this year due to concern over the comparability of the fishery in recent years to that of the past. The resulting formulation was as follows:

Ca,y=catch; a=1 to 9, y=1983-1998
RVa,y=Canadian July RV; a=1 to 6, y=1983-1998

Natural mortality was assumed constant and equal to 0.4, and errors in the catch at age were assumed to be without error relative to the abundance indices. F at age 9 was calculated as the average of ages 4 to 6 in the same year, and a dome was not forced.

Parameter estimates from the analysis are show in Table 9. Bias adjusted beginning of year population numbers, fishing mortality, and population biomass are shown in Tables 10, 11 & 12. Population biomass (2+) estimated from the model, the q-adjusted survey index, and a graphical representation of the scaled residuals from the ADAPT are shown in Fig. 21.

In past assessments of this resource (Showell, 1998), population numbers have shown changes with the addition of data in subsequent years, with a tendency for the current estimate of population size to be overly optimistic. As a result, an analysis for a retrospective pattern was conducted. The retrospective effect on age 2+ biomass (ie the proportion of the fishery important to the commercial fishery) is presented in Fig. 22. To quantify the effect of the retrospective pattern, an analysis of initial estimates of population numbers compared to the most recent estimates was conducted, and the proportion of the 1998 estimate to the initial estimate was averaged for the past 8 years. When the initial estimate was compared to the estimate with several more years data added, a difference of 30 to 57% was seen in ages 1 though 4 with higher levels for older ages (Table 13). Fishing mortality for the fully recruited age groups (ages 4-6), was severely underestimated as well (Fig. 22). In the previous assessment of this resource (Showell, 1998), the magnitude of the retrospective pattern was much smaller (17 to 23%) and an approach was adopted whereby SPA numbers were discounted prior to projection. Given the size of the reductions required in the current reconstruction of the population, this approach is not considered appropriate, and a reliable projection of yield is not possible.

Estimates of Total Mortality (Z)

The mean numbers per tow index from the July survey was used to calculate total mortality. To reduce variability in the estimates, the results were grouped into age classes (2-3, 4-5, 6-7) and smoothed using a two year moving average (Fig. 23). Based on this method, total mortality on age 2 and 3 fish (ie the age classes on which the fishery is conducted) has remained relatively high, despite a sharp decline in catches, with Z for ages 4 and 5 higher still. In recent years total mortality for the oldest ages has declined relative to that of age 4-5, likely as a result of gear changes which required use of a grate from 1994 onwards.

Recruiting Yearclass Sizes

Estimates of age 1 in the terminal year of the VPA are unreliable, as they result from a single estimate in the calibrations block, and as a consequence the best available estimate for the 1997 year class is derived from age 1 RV abundance in 1998. Using the age 1 catchability coefficient (q) for the RV age 1

from Table 9, the size of this yearclass is estimated to be below average at 220 million fish, confirming the length based estimate made last year (Showell, 1998).

The 1999 July survey has been conducted, but aging is not complete. However, a reasonable estimate of the 1998 yearclass at age 1 can be made based on abundance of fish <23 cm (Branton *et al.*, 1997). Based on this method, this yearclass is relatively strong (Fig. 24), and the abundance adjusted using RV age 1 q from the VPA is about 840 million fish.

Outlook

Given the large retrospective pattern in the estimates of population numbers, an analytical assessment of yield for this resource was not possible. However, SPA methodology is only one of several tools available to assess the population. Several other indices were available which are considered to be equally important attributes of stock status. Recruitment will likely be above average in 2000, and resource concentration and geographical range distribution exhibit positive trends. However, biomass estimates from the summer survey are very low, at levels similar to those seen during the 1970's when this stock was in decline. Further, total mortality estimates from the survey are above $F_{0.1}$ for ages important to the fishery, despite relatively low catches in recent years. The extreme values of these important indicators are cause for concern. Other attributes, such as length-at-age, condition, and size at maturity, while not at near lowest levels, are below long term averages. Under these circumstances, catches should be restricted to that seen from 1997-99.

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Table 1: Nominal catches (mt) for 4VWX silver hake 1970-1998 (1995-1999 preliminary).

Country	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982
Bulgaria	0	0	0	0	0	1722	3088	862	606	4639	817	0	0
Canada	0	0	0	0	11	101	26	10	26	13	104	6	38
Cuba	0	0	201	0	0	1724	12572	1847	3436	1798	2287	642	11969
France	0	0	0	0	0	0	0	15	0	0	0	0	2[1]
FRG	0	0	10	0	296	106	97	684	0	0	0	0	0
GDR	0	0	0	0	0	0	0	0	3	0	0	0	0
Ireland	0	0	0	0	0	108	106	0	0	9	0	0	0
Italy	0	0	0	0	0	0	0	38	106	5	0	541	37[1]
Japan	129	8	63	88	67	54	78	19	161	219	239	120	937
Poland	0	0	0	0	0	0	0	295	2	0	0	1[1]	31[2]
Portugal	0	0	0	0	0	0	0	0	0	0	56	2044	2[1]
Romania	0	0	0	0	0	0	0	10	0	1	0	0	0
Spain	0	15	0	0	0	6	0	0	2	0	40	0	0
USA	0	1	1	1	1	7	1	14	0	0	0	3	2
USSR	168916	128633	113774	298533	95371	112566	81216	33301	44062	45076	40982	41243	47261
Total	169045	128657	114048	298621	95745	116394	97184	37095	48404	51760	44525	44600	60251

Country	1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995
Bulgaria	0	0	0	0	0	0	0	88	0	0	0	0	0
Canada	15	10	2	9	13	9	337	10	34	4	73	57	300[1]
Cuba	7418	14496	17683	16041	20219	9016	14541	13888	23708	16528	22018	7788	16835[1]
France	0	0	0	0	0	0	0	0	0	0	0	0	0
FRG	0	0	0	0	0	0	0	0	0	0	0	0	0
GDR	0	93	0	0	0	0	0	0	0	0	0	0	0
Ireland	0	0	0	0	0	0	0	0	0	0	0	0	0
Italy	2[2]	0	0	0	0	0	0	0	0	0	0	0	0
Japan	649	530	120	66	144	0	194	315	781	547	0	0	0
Poland	0	0	0	0	0	0	0	0	0	0	0	0	0
Portugal	378	1714	1338	0	0	0	0	0	0	0	0	0	0
Romania	0	0	0	0	0	0	0	0	0	0	0	0	0
Spain	0	0	0	0	0	0	0	0	0	0	0	0	0
USA	0	0	0	1	0	0		0	0	0	0	0	0
USSR	27377	57423	56337	66571	41329	65349	72917	55429	40786	14716	7139[1]	0	0
Total	35839	74266	75480	82688	61705	74374	87989	69730	65309	31795	29230	7845	17835

[1] Observer Program Data (data not reported to NAFO)
[2] FLASH data

Country	1996	1997	1998	1999*
Bulgaria	0	0	0	0
Canada	3473	4203	9979	4961
Cuba	21773[1]	11961[1]	6083[1]	3897[1]
France	0	0	0	0
FRG	0	0	0	0
GDR	0	0	0	0
Ireland	0	0	0	0
Italy	0	0	0	0
Japan	0	0	0	0
Poland	0	0	0	0
Portugal	0	0	0	0
Romania	0	0	0	0
Spain	0	0	0	0
USA	0	0	0	0
USSR	669	0	168	0
Total	25927	16,164	16062	8858

[1] Observer Program Data (data not reported to NAFO)
[2] FLASH data
*incomplete

Table 2: Length/weight regressions: Male and female alpha and beta's used in the construction of the silver hake catch at age used in this assessment. Lengths (cm) and weights (kg) used were from the Canadian July Research Vessel Survey of the Scotian Shelf (4VWX).

Year	Male - Alpha	Female - Alpha	Male - Beta	Female - Beta
1977	0.000006260	0.000006930	3.0626	3.0350
1978	0.000004630	0.000003070	3.1366	3.2531
1979	0.000010200	0.000005880	2.9001	3.0675
1980	0.000002330	0.000001800	3.3417	3.3989
1981	0.000006830	0.000005080	3.0206	3.1172
1982	0.000011600	0.000006740	2.8575	3.0232
1983	0.000006480	0.000003320	2.9935	3.2034
1984	0.000018300	0.000006490	2.7052	3.0284
1985	0.000013500	0.000004530	2.7848	3.1235
1986	0.000007970	0.000003820	2.9384	3.1685
1987	0.000009990	0.000004240	2.8798	3.1456
1988	0.000014300	0.000004800	2.7942	3.1241
1989	0.000006750	0.000004440	3.0114	3.1416
1990	0.000034320	0.000021000	2.5234	2.6958
1991	0.000007773	0.000003488	2.9582	3.2036
1992	0.000003938	0.000003157	3.1824	3.2533
1993	0.000003461	0.000003089	3.178	3.2202
1994	0.000003336	0.000003147	3.2009	3.2228
1995	0.000003340	0.000002367	3.2151	3.3233
1996	0.000002548	0.000002460	3.2909	3.3040
1997	0.000002939	0.000002479	3.2511	3.3050
1998	0.000003682	0.000003049	3.1783	3.2390
1999	0.000002822	0.000002998	3.2564	3.2392

Table 3: Catch at age ('000's) for Scotian Shelf silver hake in 1998 by Cuban vessels.

6083t	age								
	1	2	3	4	5	6	7	8	9
March	0.1	761.9	1655.2	821.0	32.7	7.1	0	0	0
April	0	1711.5	4973.0	2170.0	279.0	0	0	0	0
May	0	3147.6	8350.3	2493.9	250.0	13.7	0	0	0
June	11.3	5999.5	6788.3	2064.5	356.2	6.1	19.9	0	0
July	59.8	2299.2	2108.6	660.4	83.1	5.1	1.7	0.5	0
Total	71.3	13919.7	23875.4	8209.8	1001.0	32.0	21.6	0.5	0
%	0.2	29.5	50.7	17.4	2.1	0.1	0.0	0.0	0.0

Table 4: Catch at age ('000's) for Scotian Shelf silver hake in 1998 by Canadian vessels.

9979t	age								
	1	2	3	4	5	6	7	8	9
q1	0	0	2157.0	1388.0	223.0	124.0	0	0	0
q2	357.0	15754.0	10751.0	350.0	45.3	23.6	0	0	0
q3	3946.0	8658.0	1727.0	641.6	182.3	63.6	0	0	0
q4	9858.0	5686.0	1801.0	858.0	148.0	10.3	0	0	0
total	14161.0	30098.0	16436.0	3237.6	598.6	221.5	0	0	0
%	21.9	46.5	25.4	5.0	0.9	0.3	0	0	0

Table 5: Catch at age ('000's) for Scotian Shelf silver hake, 1979-98 – all fleets combined.

age	1	2	3	4	5	6	7	8	9
1979	20569	57893	72891	36669	22380	9970	3168	495	374
1980	16588	70696	70391	32032	14465	5184	1431	451	98
1981	2358	25214	109035	37573	11928	3234	1201	290	141
1982	20189	52976	75876	68400	31752	5945	2042	465	64
1983	5849	96852	56158	29282	11388	3395	819	253	88
1984	59588	45828	206900	82911	19344	4268	1038	183	10
1985	14970	130814	98346	128365	34110	9327	2344	226	85
1986	45598	70269	229126	84097	28635	8760	1436	497	111
1987	6804	214235	114417	54211	13063	6045	347	156	117
1988	5110	62791	265307	39242	21303	3106	2133	208	143
1989	24264	85846	158745	145105	20025	9369	1569	1166	39
1990	6516	209620	142862	41215	11741	1648	640	107	40
1991	5738	117305	201243	46414	12154	3954	290	181	50
1992	7461	74491	73526	27777	3461	1247	159	33	5
1993	31572	83140	70735	35222	5511	595	71	30	3
1994	1651	13265	35250	8847	1283	150	18	8	0
1995	3500	35925	45615	31316	5183	457	58	41	3
1996	33501	92030	43686	23234	4928	888	148	75	0
1997	16132	34018	37497	25384	3579	339	29	27	2
1998	14232	44018	40311	11447	1690	235	22	4	0

Table 6: CPUE (t/hr) and effort (hrs), raw and (corrected) for the effect of separator grates, for the Cuban and Russian 4VWX silver hake fishery, 1979-99.

year	CPUE	effort (hrs)
1979	1.71	30,271
1980	2.04	21,811
1981	1.71	26,083
1982	3.20	18,841
1983	1.76	20,406
1984	2.94	25276
1985	2.82	26,791
1986	3.48	23,755
1987	2.75	22,433
1988	2.80	26,535
1989	3.89	22,624
1990	1.89	37,288
1991	1.70	39,911
1992	1.32	24,148
1993	1.43	20,369
1994	1.36 (1.43)	5,767 (5,479)
1995	1.34 (1.41)	12,519 (11,893)
1996	1.28 (1.34)	17,010 (16,160)
1997	1.02 (1.07)	11,726 (11,140)
1998	1.35 (1.42)	4,505 (4,280)
1999	0.88 (0.92)	4,428 (4,207)

Table 7: Scotian Shelf silver hake July RV survey numbers ('000) at age, (strata 484-495 excluded). 1977 to 1982 corrected for vessel effect.

year	1	2	3	4	5	6	7	8	9
1977	4678	23530	19417	4565	1361	1213	938	327	284
1978	23504	22781	16119	8923	6696	3050	1288	502	866
1979	69803	146692	69097	20341	11565	5083	2683	976	277
1980	11491	19280	28116	7884	4292	3358	1478	805	382
1981	31646	84254	129884	60439	16084	5237	2428	794	654
1982	177636	29113	7743	6201	3210	817	350	252	33
1983	41989	99363	38242	18996	10603	2779	882	401	333
1984	174499	65030	209275	39603	12120	8042	2873	1141	523
1985	37657	163470	33877	73811	22537	9947	2662	1224	215
1986	262382	73829	74006	22644	13552	4148	1656	714	334
1987	139673	253815	42291	18612	6068	4104	1256	669	477
1988	68466	87117	82662	16966	14226	2514	2373	481	148
1989	128836	60127	23090	13012	3549	1744	697	318	129
1990	89477	115013	46417	13857	4057	1155	407	208	81
1991	39736	80924	35098	13165	6624	2417	402	143	124
1992	25952	56010	45726	11077	4464	2230	423	139	192
1993	113930	89870	63214	27290	2531	807	584	98	38
1994	86323	56315	57237	25354	8180	1147	331	210	133
1995	90254	72148	82582	56655	15599	3415	1295	614	652
1996	94124	170255	57251	42983	10622	1584	295	567	156
1997	143034	122443	53562	6064	3663	594	88	77	77
1998	34000	92900	35200	13700	2100	1300	280	100	100

Table 8: Stratified mean catch per tow for the Canada-Russia juvenile silver hake survey, core strata (60-78).

Year Class	1981	1982	1983	1984	1985	1986	1987	1988	1989
mean catch/tow	579.0	8.8	232.2	43.4	284.8	198.0	102.0	204.8	131.5
std.error	64.4	1.2	24.4	7.1	62.2	37.9	23.0	35.3	19.0
CV	0.11	0.14	0.11	0.16	0.22	0.19	0.23	0.17	0.14
number of sets	77	61	64	71	82	74	105	79	74
July RV age 1 #'s (10^6)	178	42	175	38	262	140	68	129	89

Ycar Class	1990	1991	1992[1]	1993	1994	1995	1996	1997
mean catch/tow	187.4	78.6	-	186.5	105.4	252.0	444.1	578.6
std.error	24.1	10.4	-	17.2	8.4	60.5	186.5	214.1
CV	0.13	0.13	-	0.09	0.08	0.24	0.42	0.37
number of sets	68	71	-	95	73	83	81	81
July RV age 1 #'s (10^6)	40	26	114	86	90	94	143	--

[1] no survey in 1992.

Table 9: Parameter estimates from ADAPT analysis for Scotian Shelf silver hake; July RV abundance at age used as tuning index.

Est.	Parar	SE	CV	Bias	
1	12.0565	0.918075	0.0761475	-0.00643	f1
2	12.7188	0.870579	0.0684481	0.13739	f2
3	11.6231	1.55832	0.134071	2.09656	f3
4	10.6733	0.62688	0.0587337	0.20207	f4
5	7.67372	1.18471	0.154386	1.48064	f5
6	6.97489	1.6581	0.237724	3.25563	f6
7	1.53137E-005	3.33477E-006	0.217764	-0.251059	q1
8	2.80064E-005	5.93872E-006	0.212049	-0.651266	q2
9	3.9855E-005	8.41036E-006	0.211024	-1.60641	q3
10	6.51858E-005	1.36005E-005	0.208642	-0.148929	q4
11	0.000108786	2.32477E-005	0.213701	-1.3064	q5
12	0.000177426	3.80767E-005	0.214606	-3.17273	q6

Table 10: SPA results – bias corrected population numbers.

1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
830906	1379660	757154	1865128	807386	766597	1108327	578833	410995	417547	318292	317012	545088	587118	863005	271136
1032970	552184	876027	495279	1212900	535636	509682	723068	382668	270801	273782	187509	211148	362518	366129	565282
352457	613125	332619	480117	274464	637630	307639	271365	313065	160469	120535	115452	114830	112124	167655	217572
105428	190281	241594	142442	134240	90302	210201	76247	64936	45090	47368	22884	48530	39627	39392	81683
31356	46697	59667	56849	26629	45599	28403	22100	17366	5527	7483	2914	8096	6891	7540	5622
7207	11695	15464	12069	14663	7155	13125	2644	5202	1690	871	504	903	1184	584	2124
1651	2051	4345	2730	918	4880	2253	1127	423	249	112	97	215	231	66	114
345	436	525	993	654	331	1524	226	232	46	37	17	50	97	34	21
227	24	142	167	259	311	52	67	64	7	4	0	5	0	3	1

1+

2362546	2796153	2287539	3055775	2472113	2088442	2181206	1675677	1194950	901426	768483	646389	928865	1109789	1444409	1143555

Table 11: SPA results – bias corrected fishing mortality.

1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
0.01	0.05	0.02	0.03	0.01	0.01	0.03	0.01	0.02	0.02	0.13	0.01	0.01	0.07	0.02	0.07
0.12	0.11	0.20	0.19	0.24	0.15	0.23	0.44	0.47	0.41	0.46	0.09	0.23	0.37	0.12	0.10
0.22	0.53	0.45	0.87	0.71	0.71	0.99	1.03	1.54	0.82	1.26	0.47	0.66	0.65	0.32	0.26
0.41	0.76	1.05	1.28	0.68	0.76	1.85	1.08	2.06	1.40	2.39	0.64	1.55	1.26	1.55	0.19
0.59	0.71	1.20	0.96	0.91	0.85	1.97	1.05	1.93	1.45	2.30	0.77	1.52	2.07	0.87	0.46
0.86	0.59	1.33	2.10	0.70	0.76	2.05	1.43	2.64	2.32	1.80	0.45	0.96	2.48	1.23	0.15
0.93	0.96	1.08	1.03	0.62	0.76	1.90	1.18	1.82	1.51	1.49	0.26	0.40	1.52	0.76	0.26
2.27	0.72	0.75	0.94	0.34	1.45	2.72	0.86	3.10	2.08	4.57	0.87	5.53	2.97	3.77	0.26
0.62	0.68	1.19	1.47	0.76	0.79	1.96	1.19	2.21	1.72	2.16	0.62	1.35	1.94	1.22	0.26

avg4-6

0.62	0.68	1.19	1.47	0.76	0.79	1.96	1.19	2.21	1.72	2.16	0.62	1.35	1.94	1.22	0.26

Table 12: SPA results – bias corrected population biomass.

1983	1984	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
37713	62619	38024	86854	28558	19628	28795	22818	17432	11371	21715	14733	19272	27287	21832	9355
111189	54613	85474	49180	96324	42363	39726	66033	35810	21967	25683	14524	14930	28081	23156	40959
64620	93324	53470	75950	42838	94608	50648	42769	50743	26078	17467	13806	13587	13219	19576	25743
23619	39870	47102	29964	26450	17635	42790	15684	12916	8983	9000	3654	7214	6095	6049	12617
8199	11906	13949	13026	6631	10630	7135	5124	4149	1307	1644	554	1530	1293	1394	1061
2497	3735	4380	3121	3921	1925	3954	782	1428	459	235	126	219	294	143	519
519	789	1653	928	323	1652	773	405	163	85	36	32	71	91	24	33
132	216	255	456	266	157	690	91	101	20	13	7	21	41	16	12
119	13	92	102	134	167	33	35	30	4	2	0	2	0	2	0

1+															
248608	267086	244400	259580	205444	188816	174544	153742	122770	70273	75797	47436	56847	76400	72193	90299

SSB															
155301	177160	163639	148136	128725	148007	125886	97908	87434	47919	41239	25440	30110	35073	38782	60464

Table 13: Ratio of 1998 estimates of population numbers from VPA to initial estimates from retrospective (8 year)analysis.

age	1	2	3	4	5	6	7	8	9
ratio	0.69	0.56	0.53	0.43	0.34	0.33	0.48	0.33	0.35

Table 14: Results of projection for Scotian Shelf silver hake.

Year	F	Yield(t)	Biomass(t)	SSB
1999	0.908	13999	71124	35447
2000	0.700	14220	80129	43142
2001	0.700	17220	88184	60983
2002	0.700	22055	88807	61606
2003	0.000	0	84266	57065

numbers ('000)

AGE	1999	2000	2001	2002
1	837578	432000	432000	432000
2	90244	551347	285552	285552
3	180507	52793	332741	172332
4	48115	84163	26746	168572
5	15394	13015	28015	8903
6	788	4164	4332	9326
7	585	213	1386	1442
8	19	158	71	461
9	4	5	53	24

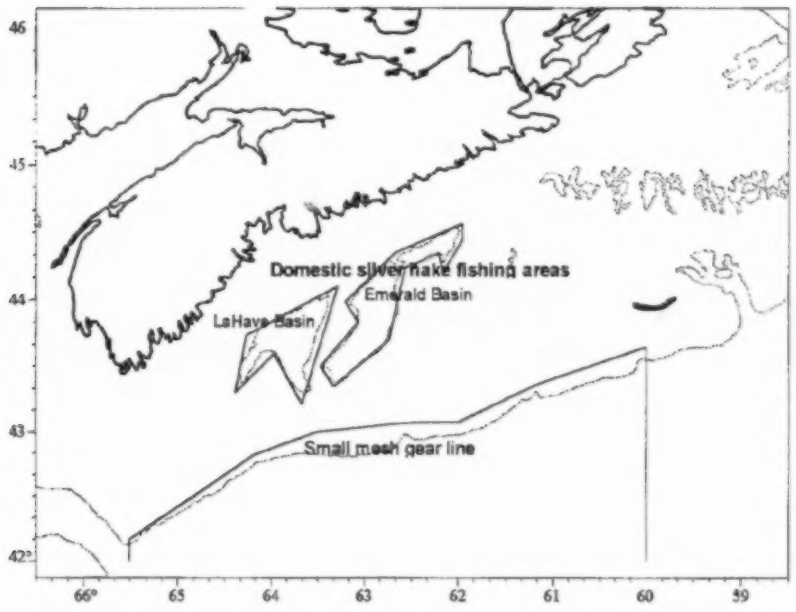


Fig. 1: Scotian Shelf silver hake fishing areas.

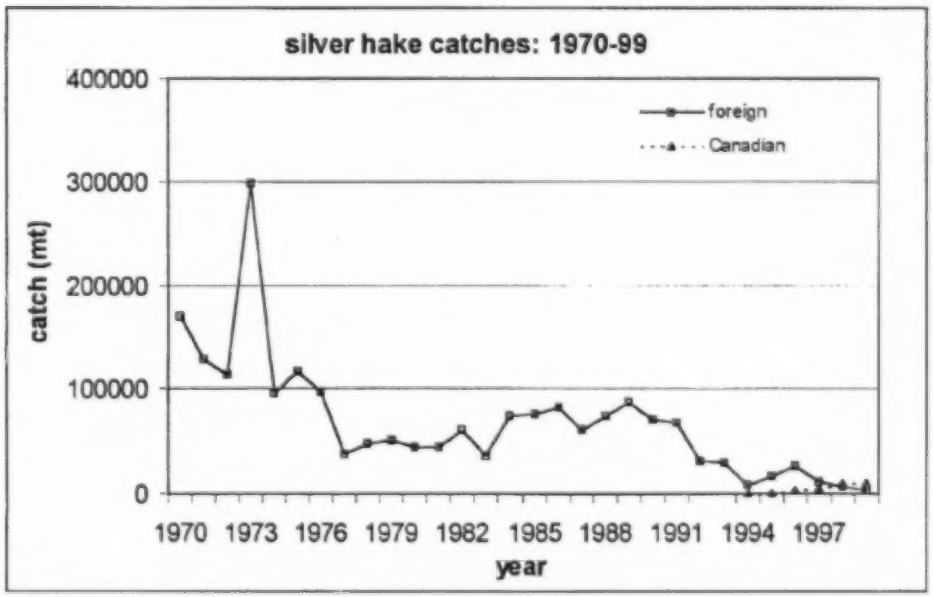


Fig. 2: Historical catches of Scotian Shelf silver hake, 1970-99 (1999 estimated).

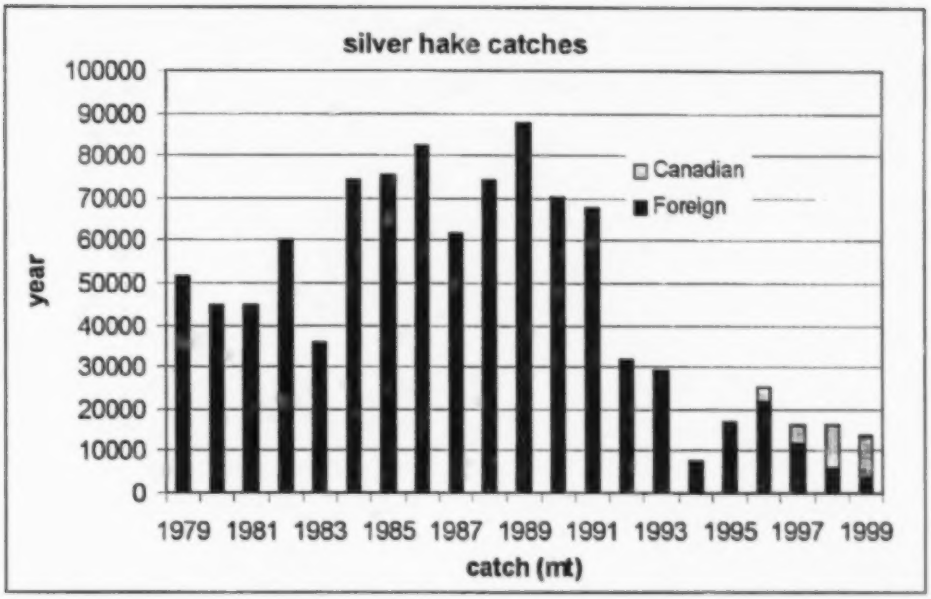


Fig. 3: Catches of Scotian Shelf silver hake by Canada and foreign fishing vessels, 1979-1999 (1999 estimated).

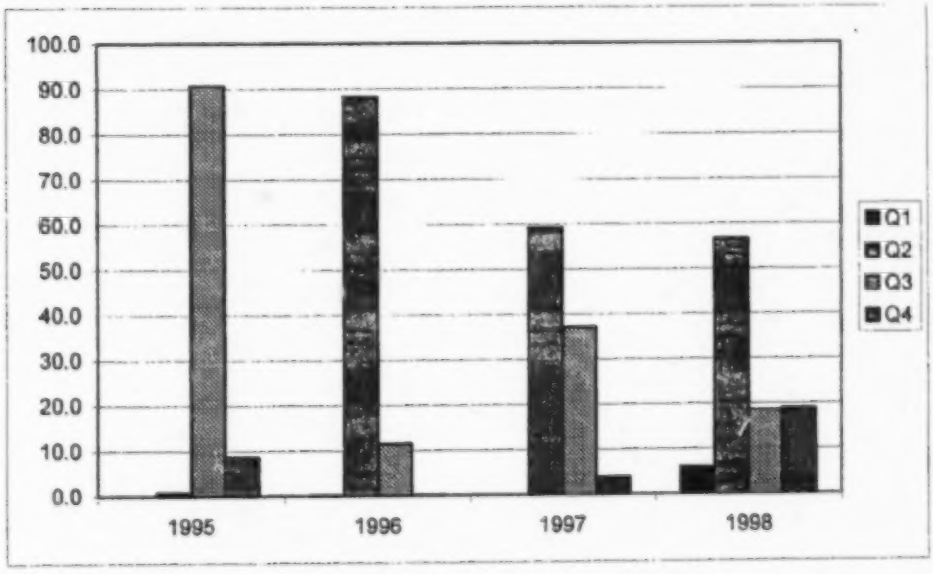


Figure 4: Silver hake catches from Emerald and LaHave Basins, 1995-98; percentage landed by quarter.

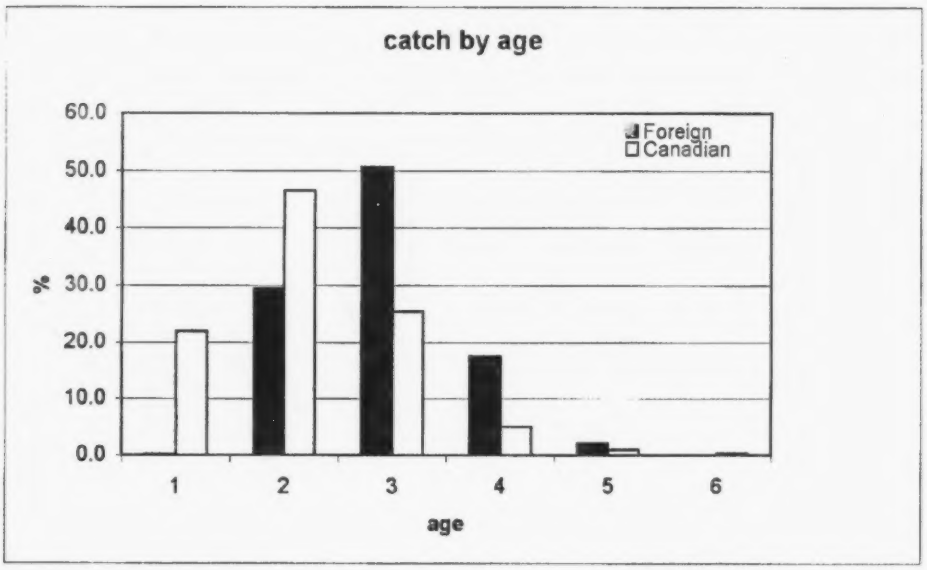


Fig. 5: Catch at age of Scotian Shelf silver hake in 1998 by Foreign and Canadian fleets.

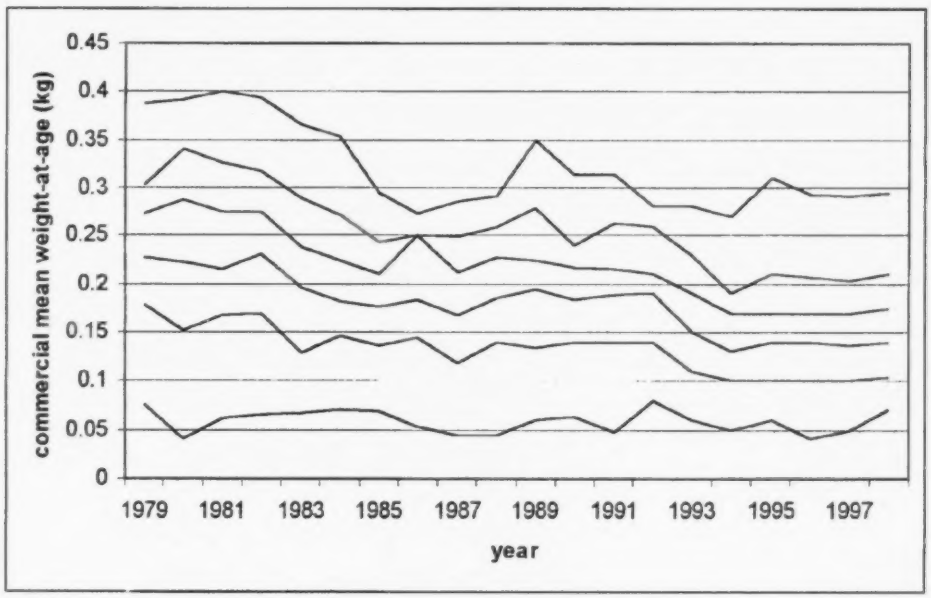


Fig. 6: Commercial mean weight-at-age for Scotian Shelf silver hake, age 1-6.

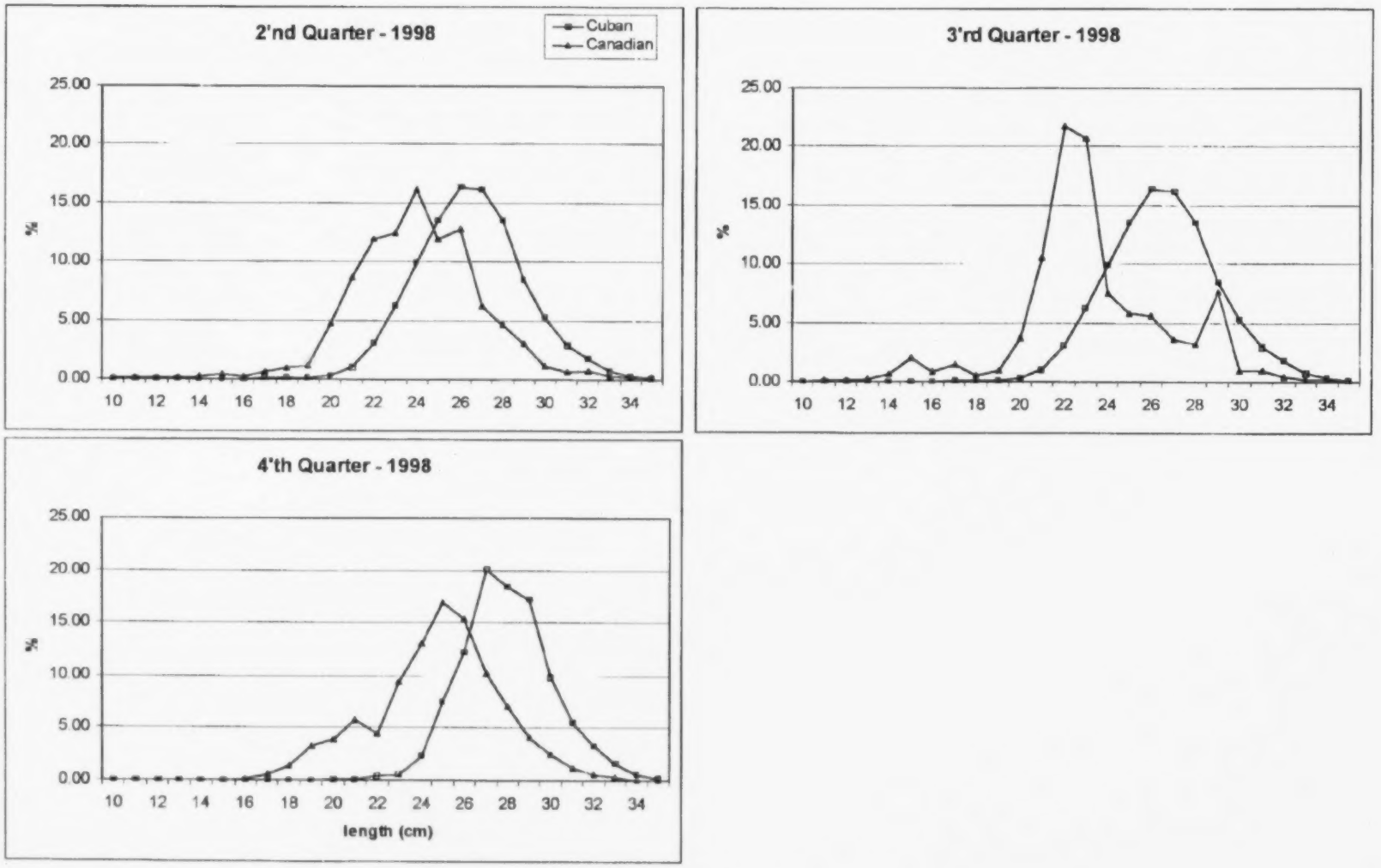


Figure 7: Comparison of size distribution of landings from the 1998 Cuban and Canadian silver hake fisheries. Cuban data from Canadian observers, Canadian data from Industry sampling.

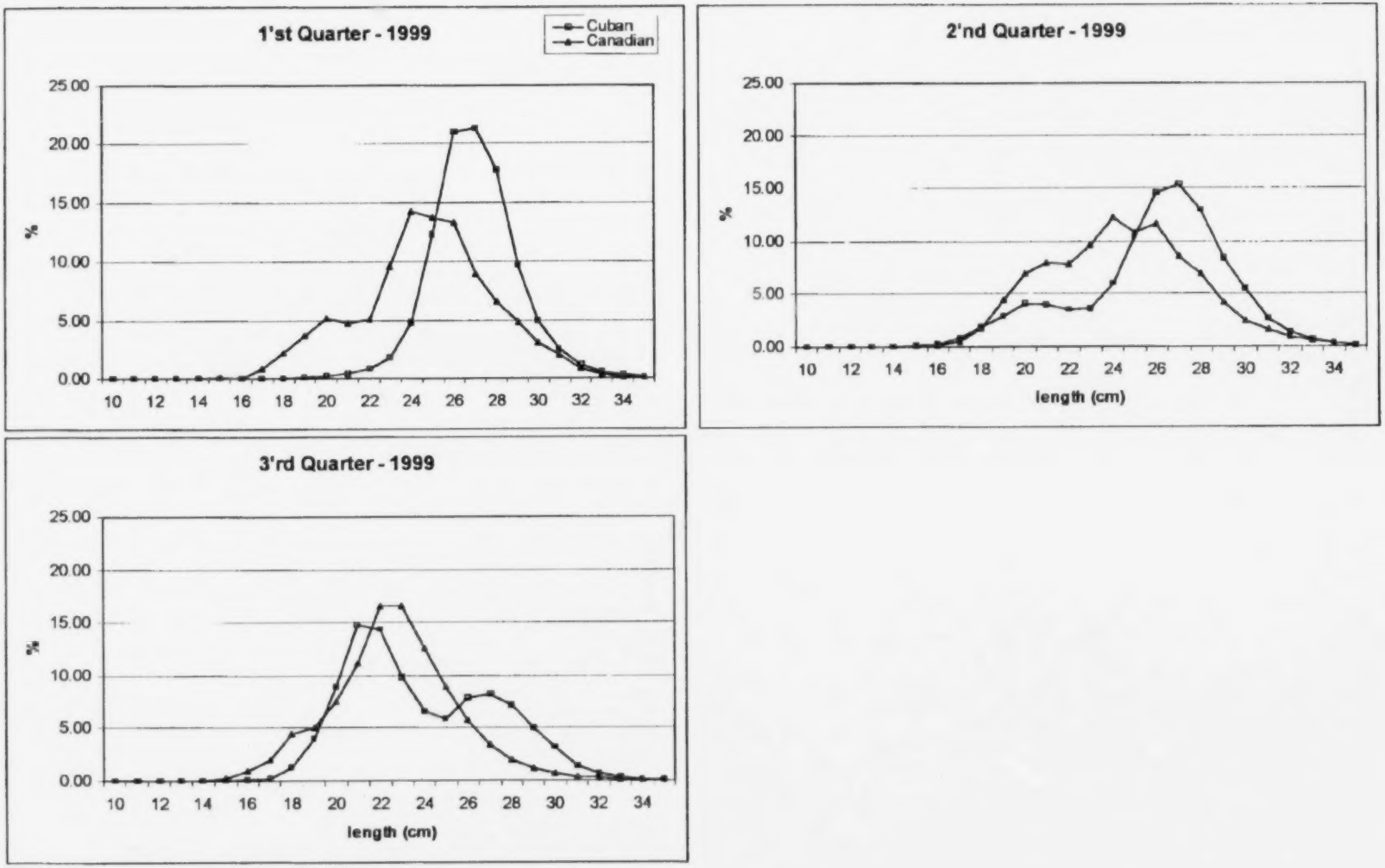


Figure 8: Comparison of size distribution of landings from the 1999 Cuban and Canadian silver hake fisheries. Cuban data from Canadian observers, Canadian data from Industry sampling and DFO port sampling.

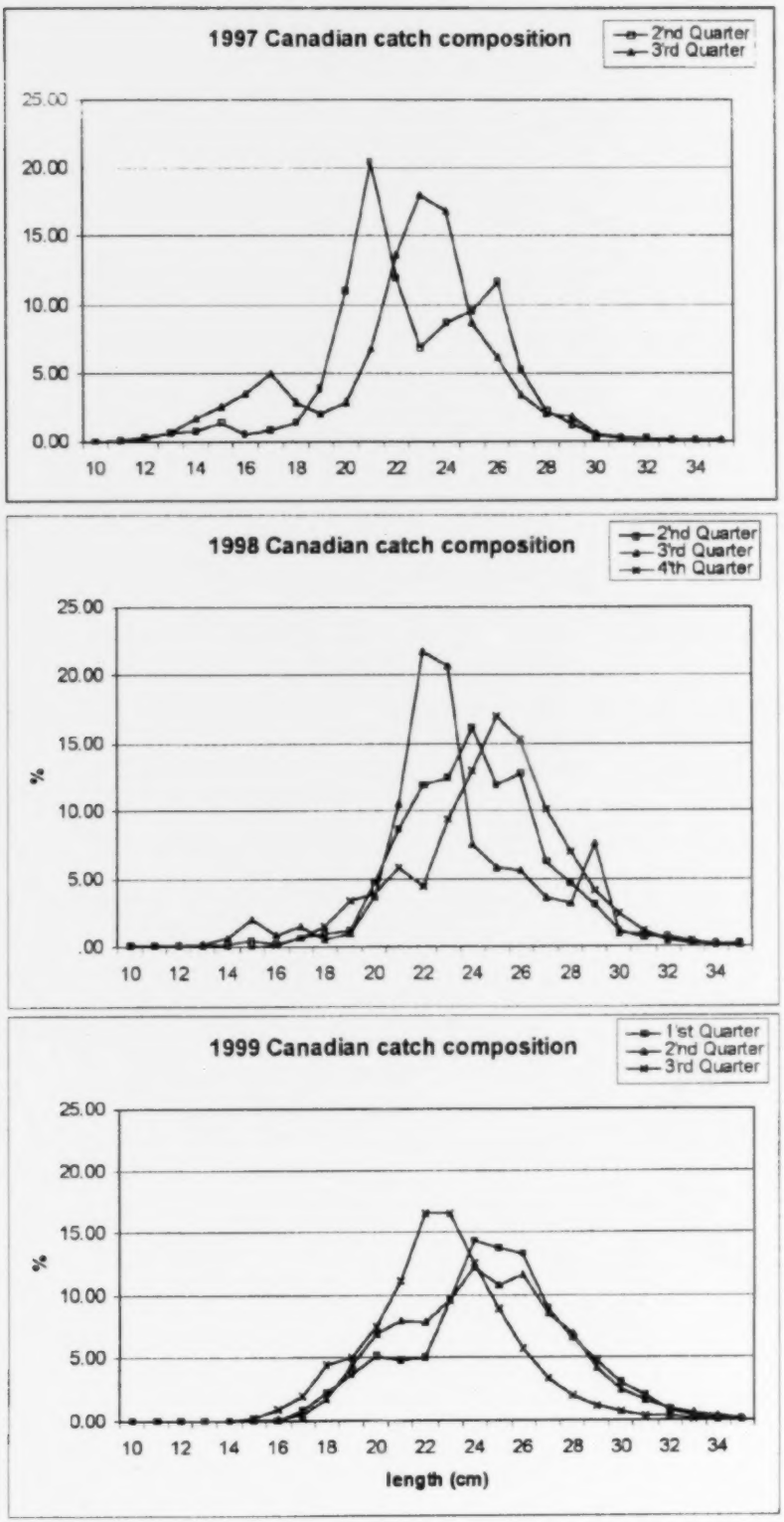


Figure 9: Comparison of size distribution of landings from the 1997-99 Canadian silver hake fishery, by quarter. 1997 & 1998 data from Industry sampling, 1999 data from Industry and DFO port sampling.

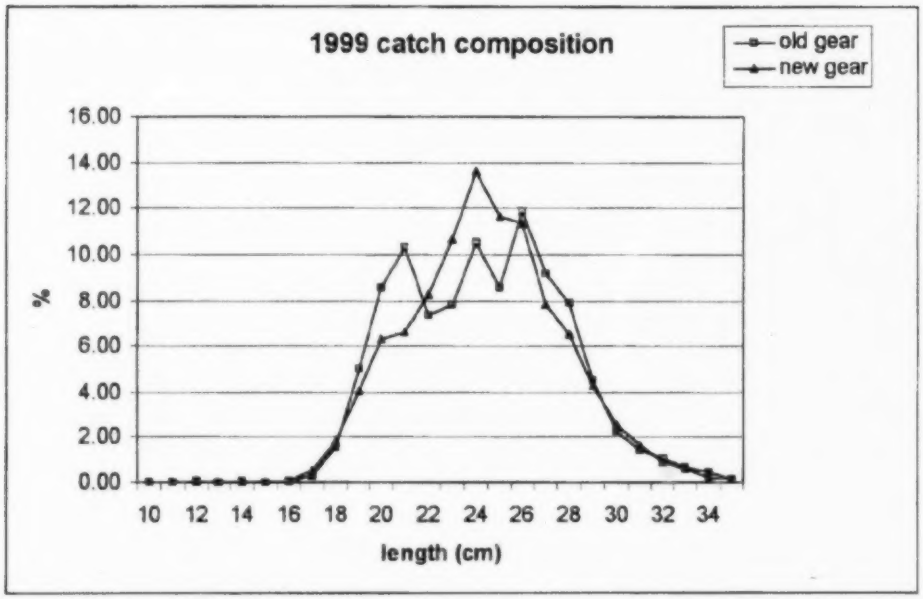


Figure 10: Comparison of size distribution of silver hake landings in April (old gear) and May (new gear) 1999. Data from Industry and DFO port sampling.

Fig 11: Commercial catch rates by foreign vessels, 1979-99 for Scotian Shelf silver hake, from Canadian observer data.

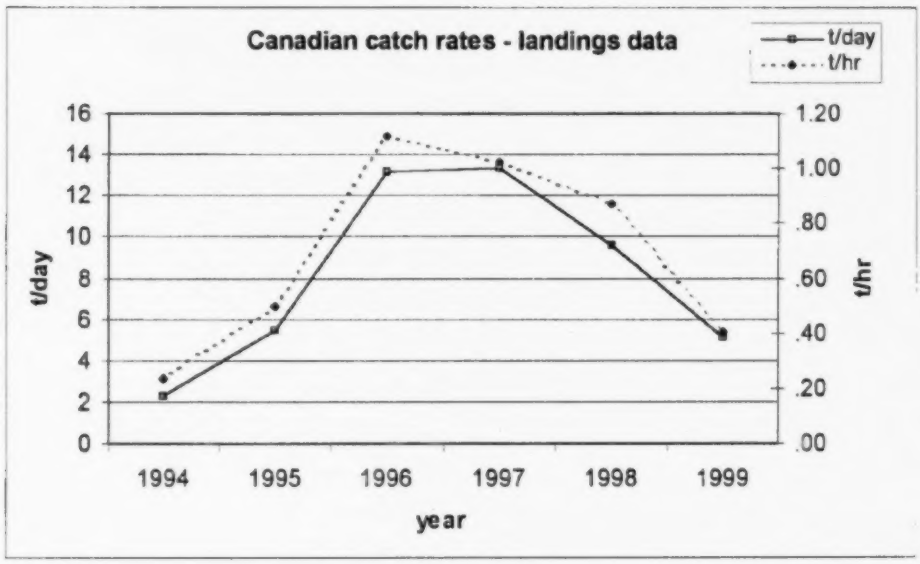


Fig 12: Commercial catch rates by Canadian vessels, 1994-99 for Scotian Shelf silver hake, from commercial landings data (1999 incomplete).

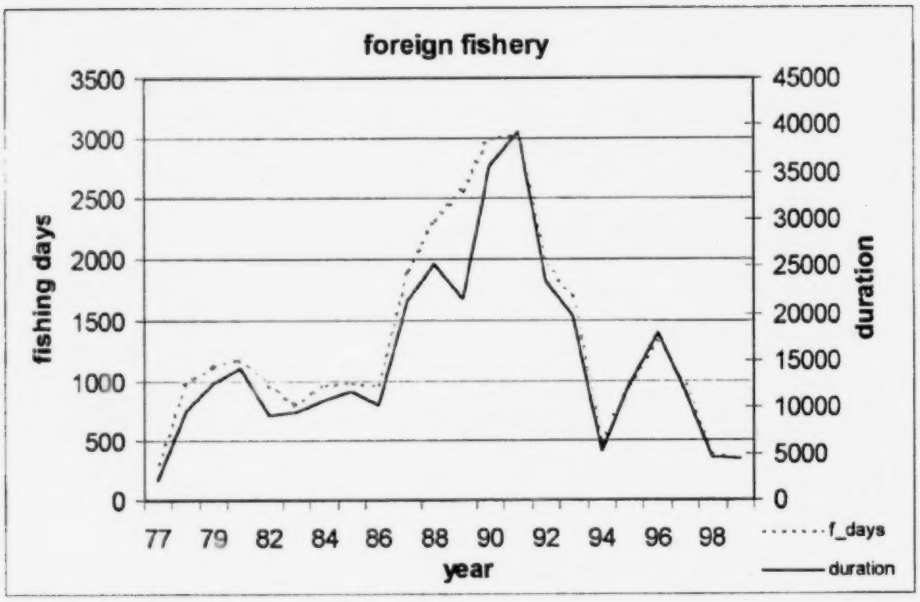


Fig 13: Fishing intensity (hours and days fished) by foreign fishing vessels on the Scotian Shelf, 1977-99.

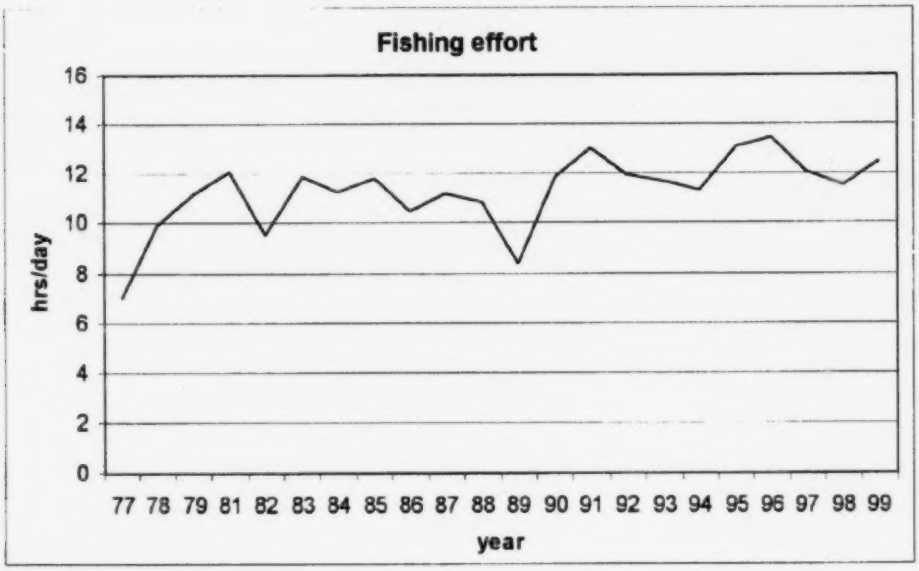


Fig. 14: Fishing effort (hours fished per day) by foreign fishing vessels on the Scotian Shelf, 1977-99.

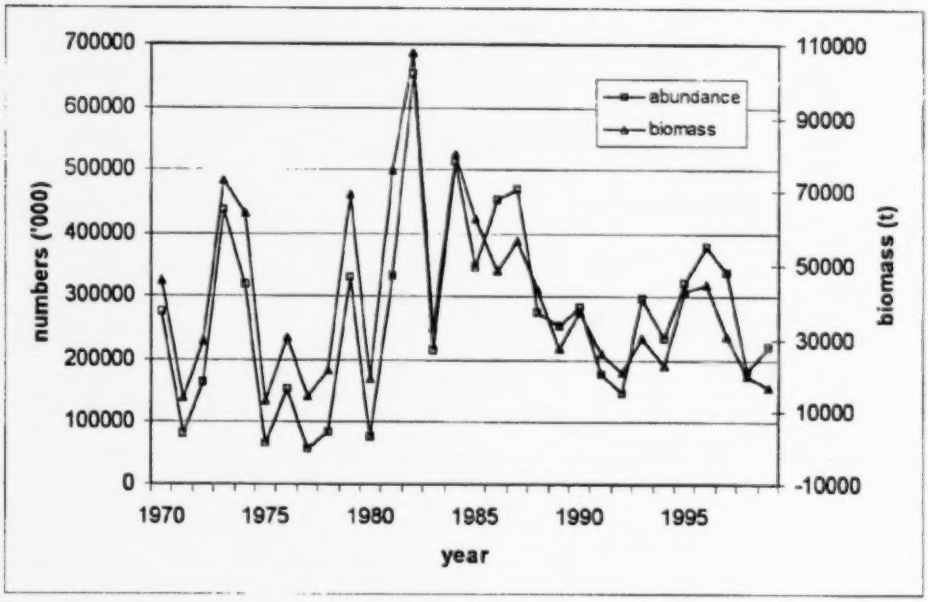


Fig. 15: Silver hake abundance and biomass estimates from Canadian RV survey, 1970-99 for Scotian Shelf strata 440-483 (excludes Bay of Fundy). Years1970-82 corrected for survey vessel effect.

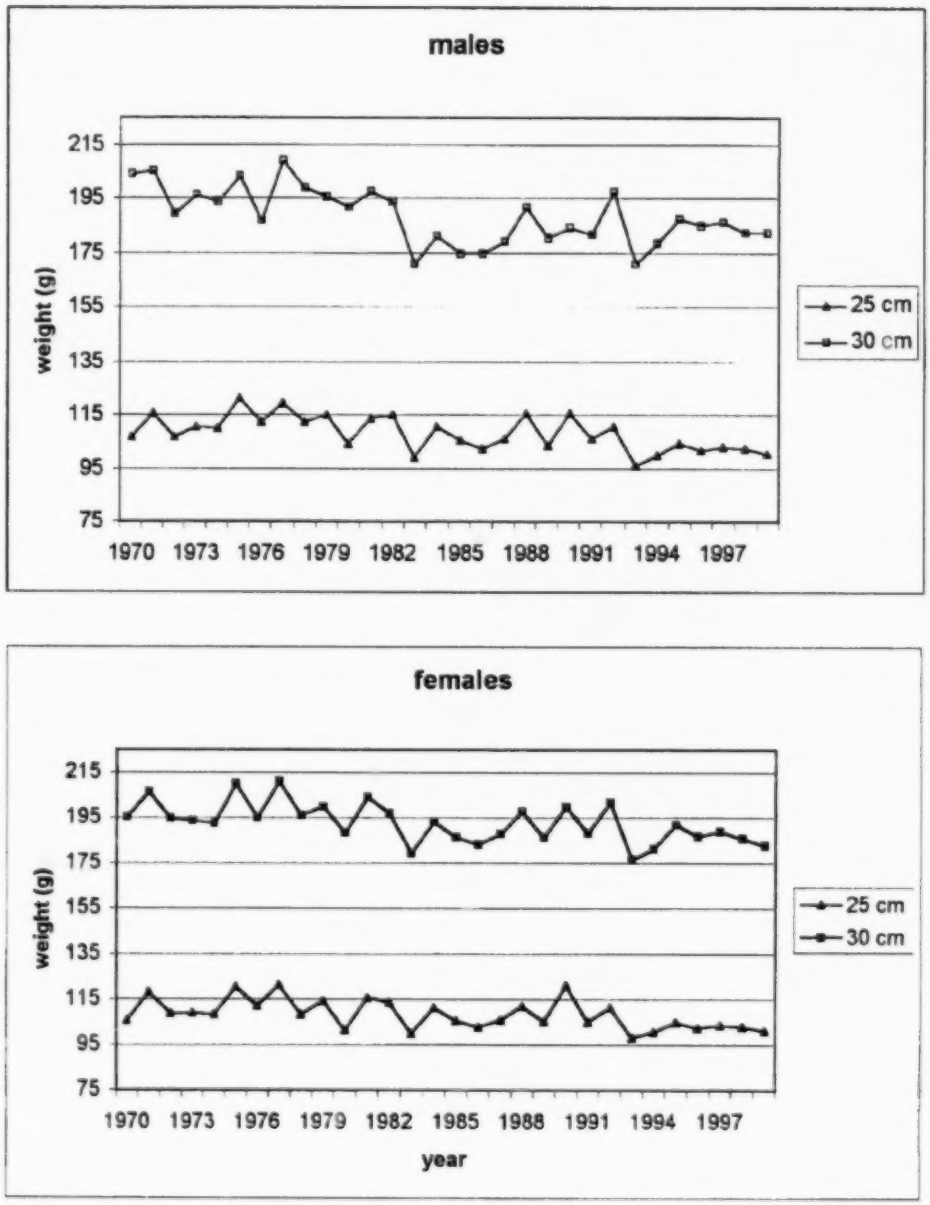
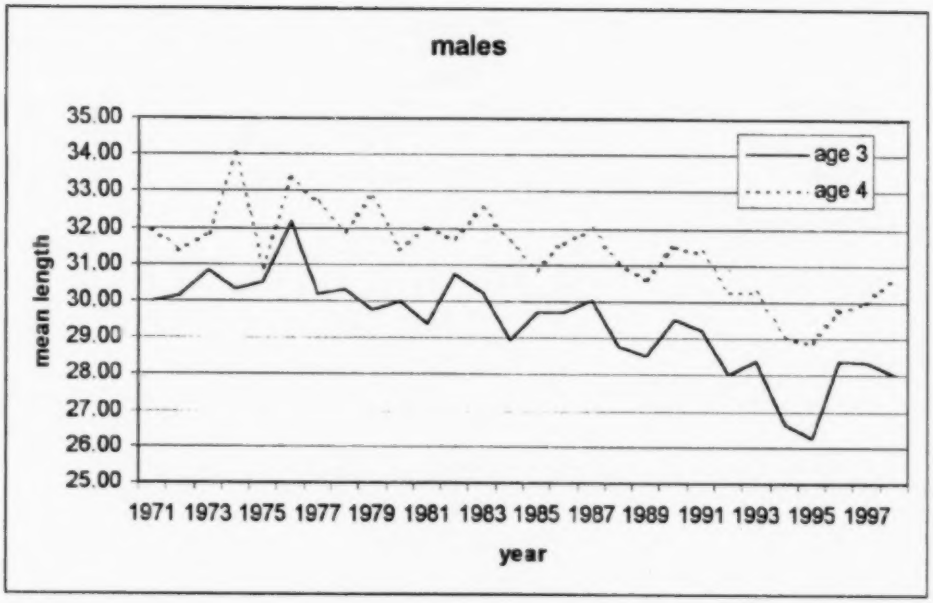


Fig. 16: Condition factor (weight at given length) for Scotian Shelf silver hake, from July RV survey data.



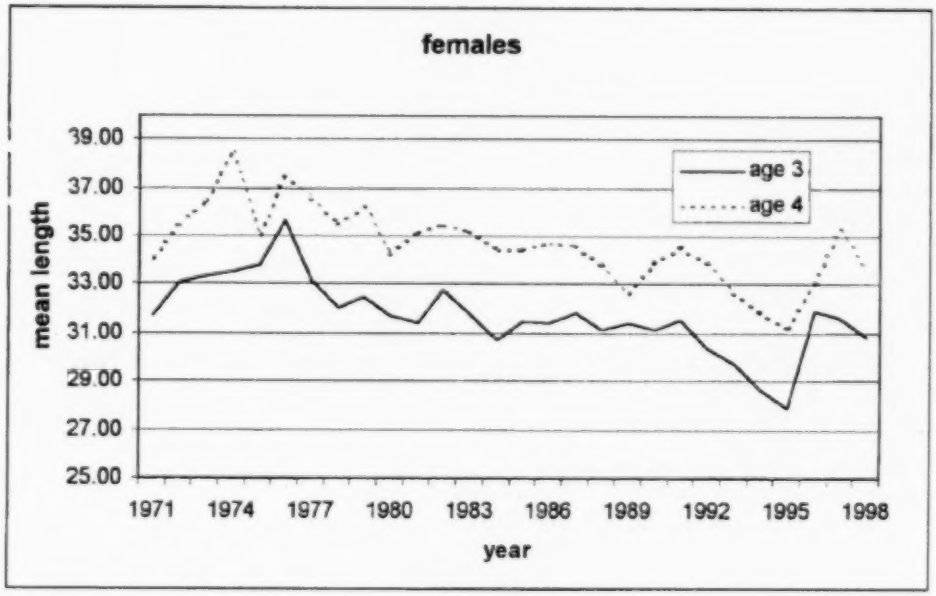
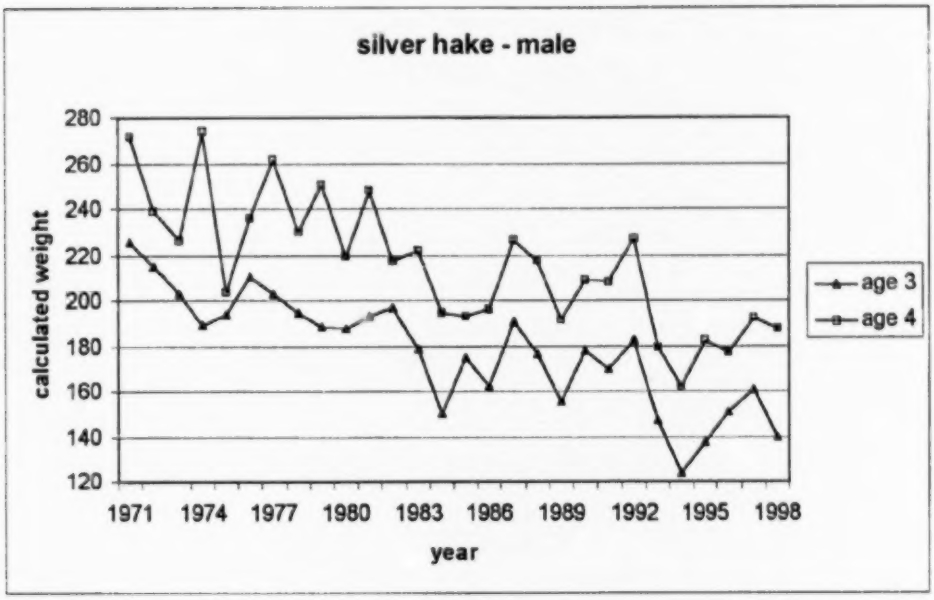


Fig. 17: Mean length at age 3 and 4, for Scotian Shelf silver hake, from July RV survey data.



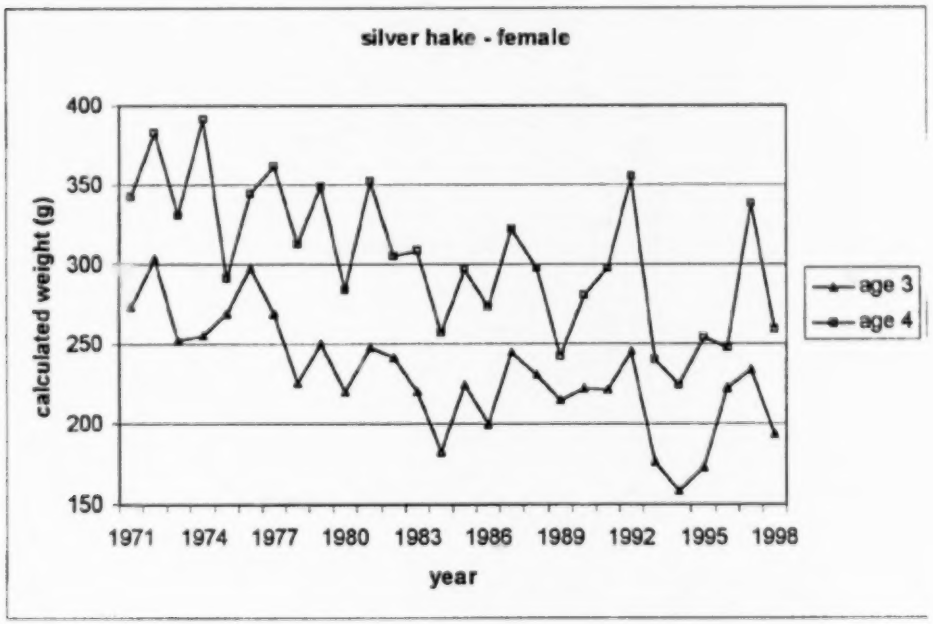


Fig 18: Calculated weight-at-age for Scotian Shelf silver hake, from July RV survey data, incorporating condition and mean length at age.

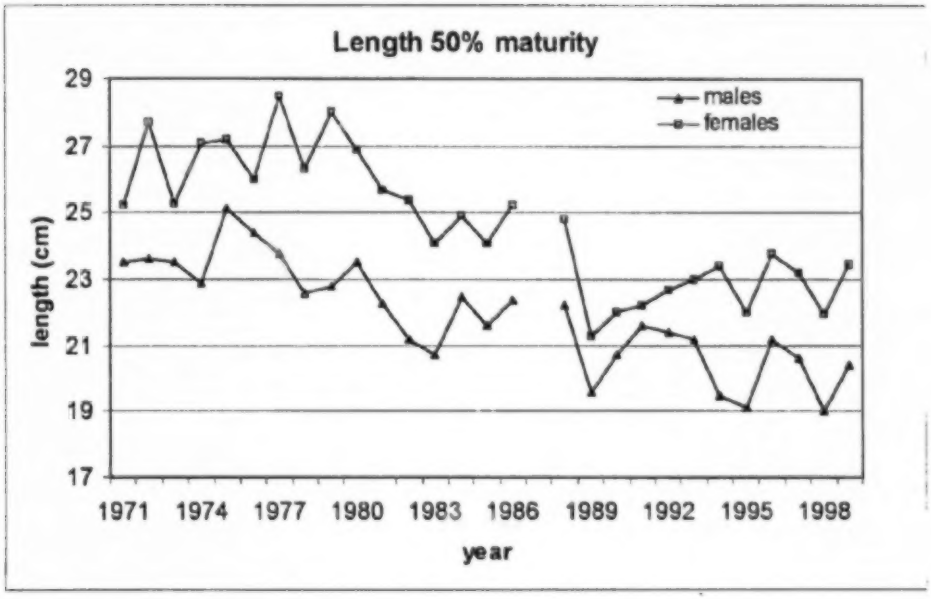
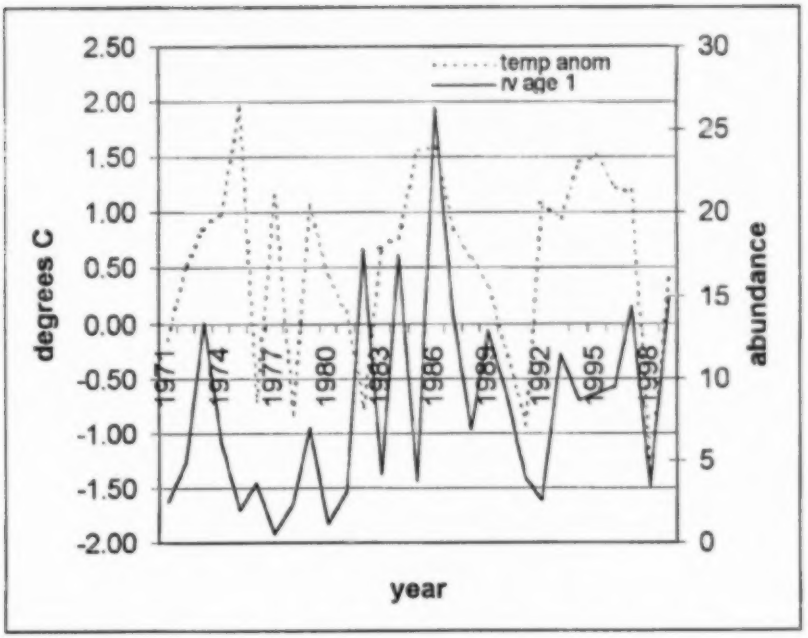


Fig. 19: Length of 50% maturity for Scotian Shelf silver hake, from probit analysis of July research survey maturity observations, 1971-98 (no data 1987).



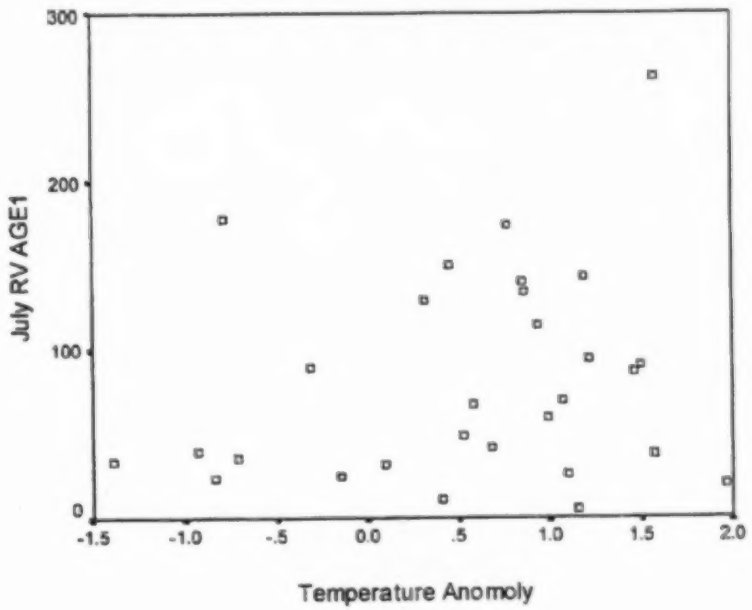


Fig. 20: Comparison of July RV estimates of silver hake abundance at age 1 to near bottom temperature anomalies in Emerald Basin, 1971-99 (1999 estimated from RV numbers at length, 1971-82 numbers adjusted for vessel effect).

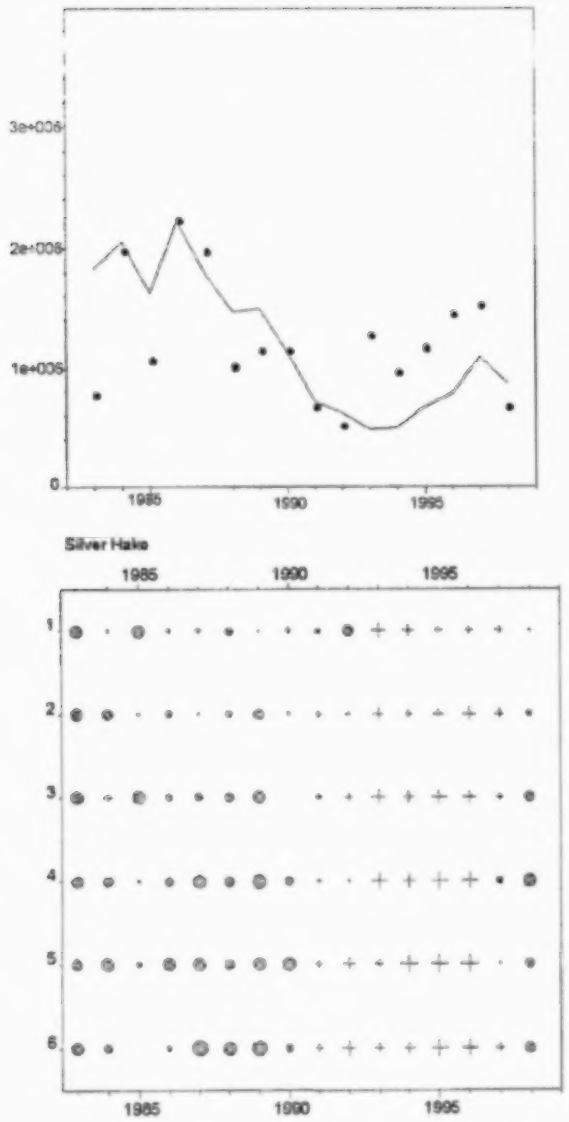


Fig 21: Population numbers (1+) estimated by SPA with q adjusted survey indices (top). Expanding symbol plot of residuals by age, bottom panel (+=positive, o=negative).

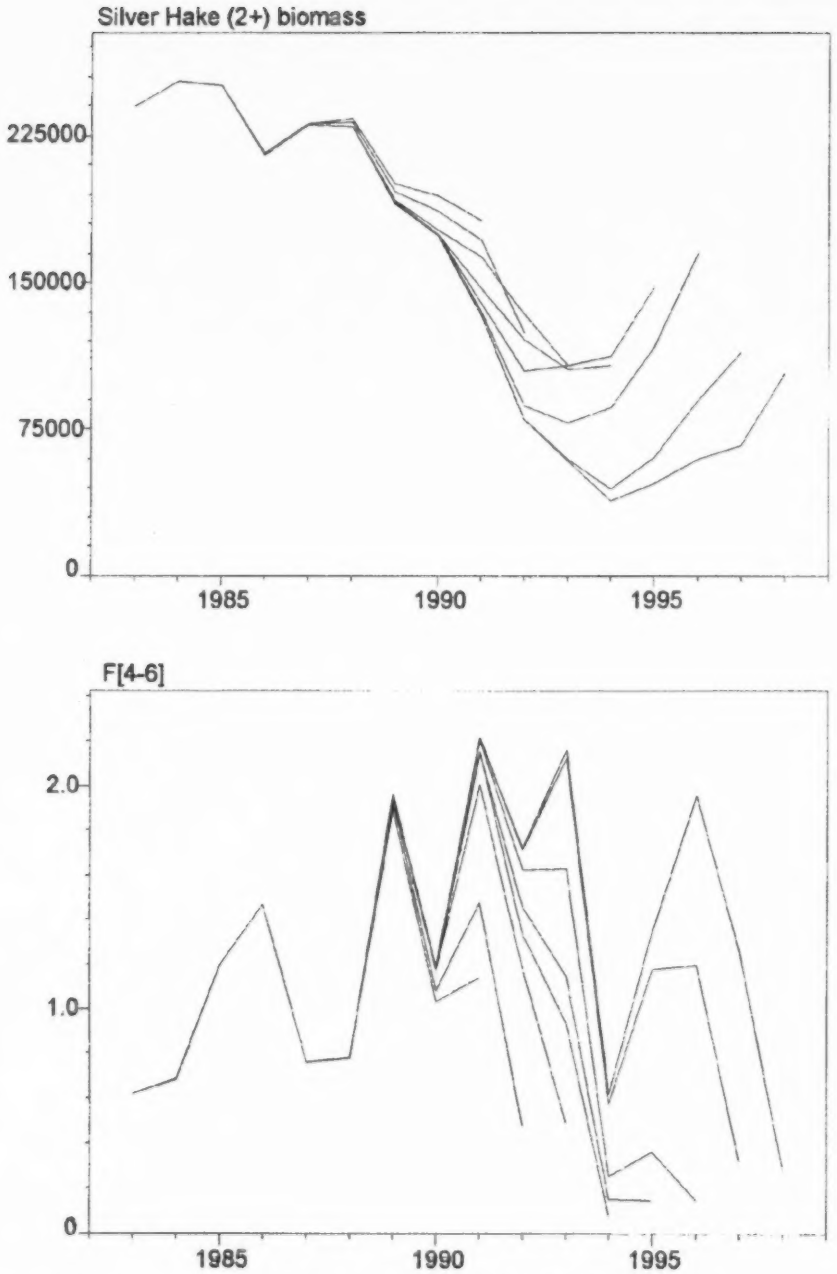


Figure 22: Retrospective analysis of SPA results for 4VWX silver hake

Fig. 23: Smoothed estimates of total mortality for Scotian Shelf silver hake from July RV abundance, grouped by ages 2-3, 4-5 and 6-7.

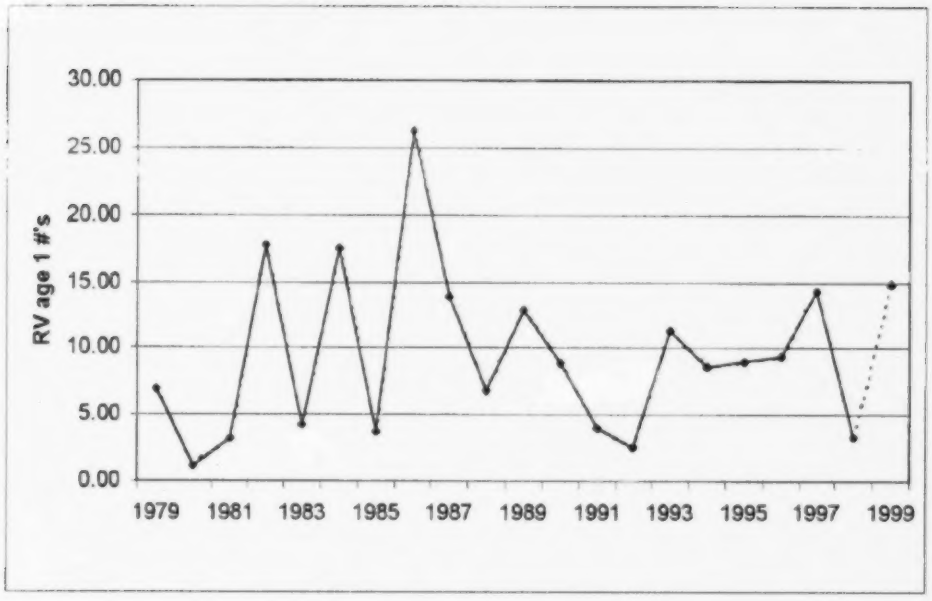


Figure 24: Recruitment estimates for Scotian Shelf silver hake, from age 1 RV abundance (1999 point estimated from length data).